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ATS-5 DESPIN-MISSION MAGNETIC INVESTIGATION

T. N. ROY
J. C. BOYLE

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GODDARD SPACE FLIGHT CENTER
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T. N. Roy
J. C. Boyle

Test and Evaluation Division
Systems Reliability Directorate

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Greenbelt, Maryland

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Prepared by:

Tom N. Roy
Magnetic Test Engineer

Joseph C. Boyle
Magnetic Test Engineer

Reviewed by:

C. Leland Parsons
Head, Magnetic Test Section

William G. Brown
Head, Functional Test Branch

Approved by:

John C. New
Chief, Test and Evaluation Division

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SUMMARY

During March and April 1970, the Goddard Space Flight Center (GSFC) Magnetic Test Site tested apparatus for determining the feasibility of the proposed magnetic-despin concept for correcting attitude problems of spacecraft already in orbit. The GSFC Mark VI torquemeter was used to measure magnetic torques at various fixer-satellite and malfunctioning-satellite separation distances and angular orientations. The varying magnetic field, that a probe on board the despin satellite would view, caused by spin of the malfunctioning satellite was also measured.

The data obtained will be used to refine the mathematical model of the actual despin system.

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FIGURE

VERY LONG BASELINE INTERFEROMETER (VLBI)

EXPERIMENTS USING ATS SATELLITES

- TEST PLAN -

I. INTRODUCTION

(a) Schedule: This document provides the test plan for two very long baseline interferometer (VLBI) experiments using ATS-3 C-band transponder and/or ATS-5 satellite L-band transponder as a radio source. The first experiment to be conducted from May 10 to June 4, 1971 using the Mojave-Rosman baseline and the ATS-3 C-band transponder as a radio source is described in detail and a complete test plan is presented. The second experiment is not described completely. However, the scope and nature of the second experiment is identical to the first one. The difference will be in the baseline and in the satellite, if the ATS-5 L-band transponder is used instead of ATS-3 C-band transponder. The second experiment is tentatively scheduled for July or August and will be run for three weeks. The baseline and satellite configuration will be selected out of the following three in the descending order of priority and availability.

1. Agassiz (Smithsonian Astrophysical Observatory) – Owens Valley (California) using ATS-5 L-band transponder (or ATS-3 C-band transponder)

2. Rosman – Owens Valley (California) using ATS-3 C-band transponder

3. Agassiz – Rosman using ATS-5 L-band transponder or ATS-3 C-band transponder

The first baseline will be chosen if the Agassiz C-band feed is modified in time to enable the antenna to receive the downlink C-band frequency from ATS-3 and/or if ATS-5 L-band transponder time is available along with a ground L-band transmitter.

The second baseline will be chosen if the Agassiz C-band feed has not been modified or if it is not possible to use the ATS-5 L-band mode. The experiment will then be run using the ATS-3 C-band transponder.

The third baseline will be used as a last resort in case Owens Valley fails.

The time schedule for the second experiment will be adjusted to fit in with the ATS ground operations and satellite time schedules.

Each experiment will be coordinated from GSFC by maintaining real-time voice communications with the two observing sites so that each mode of operation is performed according to schedule. Unforeseen delays and problems will be handled by resorting to alternate experimental mode as described under Test Schedule.

(b) Description of Experiment No. 1: (Rosman-Mojave baseline using ATS-3 C-band transponder).

Basically, the experiment will consist of Rosman transmitting a random or pseudo-random signal to the ATS-3 spacecraft. The signal will be retransmitted by the spacecraft repeater at 4119 MHZ and received simultaneously at Rosman and Mojave. The stations will record the detected signals on video tape. This is the basic VLBI experimental operation. The stations will also be required to record satellite range and range-rate data and also record signals from selected radio stars as part of the experiment. The ability to receive and record signals from radio stars will largely depend on whether or not the Rosman and Mojave antennas will be able to track a radio star. The basic input consisting of azimuth and elevation angle (or X and Y angles) as a function of time will be provided to the ground stations in whatever format necessary to conduct the tracking operation. Each tracking mode on a radio star shall last for 3 to 4 minutes. It should not be impossible to accomplish this task since the operation is similar to steering the antenna in order to track a near-earth orbit satellite. If it is determined that radio stars cannot be tracked, we will delete that function from our test plan. As can be found later in the document, inability to track radio stars will not hurt the experiment plan.

Other supporting data required from the stations will be Faraday rotation at VHF (monitoring the ATS-3 137-35 MHZ VHF beacon signal) and temperature, pressure and humidity.

II. EXPERIMENTAL HARDWARE

(a) VLBI Hardware Description: The interferometer hardware to be installed at Mojave and Rosman consists of the following items:

Video Converter
Sampler and Clipper
Time Code Generator
Sync Delay

Video Recorder
Voltage Regulator
Loran Receiver
Loran Repetition Rate Generator
Digital Clock
VLF Receiver
Chart Recorder
Rubidium Frequency Standard
Micro Clock
Buffer Amplifiers
Battery Backup

Detailed configuration of the VLBI system is shown in Figures 4, 5, 6 and 7 of the document X-551-70-432 titled "Very Long Baseline Interferometry Using ATS-3 and ATS-5 Satellites" by Ramasastry et al. The VLBI system will be interfaced with the station antenna receiver system as described in Figure 6 of the above document. The rubidium frequency standard of the VLBI system will be used to drive the station receiver system by driving the 125 MHZ synthesizer using the 5 MHZ signal from the VLBI rubidium standard.

(b) Size and Weight of VLBI System: One VLBI will be installed at both Mojave and Rosman. All the hardware except the video recorder is mounted on two racks. Each rack is 72 inches high, 19 inches wide and 36 inches deep. A schematic of the two racks with the incorporated hardware is shown in Figure 1. Net rack weights are shown below.

Table 1
Rack No. 1 (Items and Weight)

Item	Weight (lbs)
Empty Rack	180
Video Converter + Clipper	28
Recorder Chassis No. 1	8
Recorder Chassis No. 2	21
Voltage Regulator	60
Air Blower	30
Net Weight	327

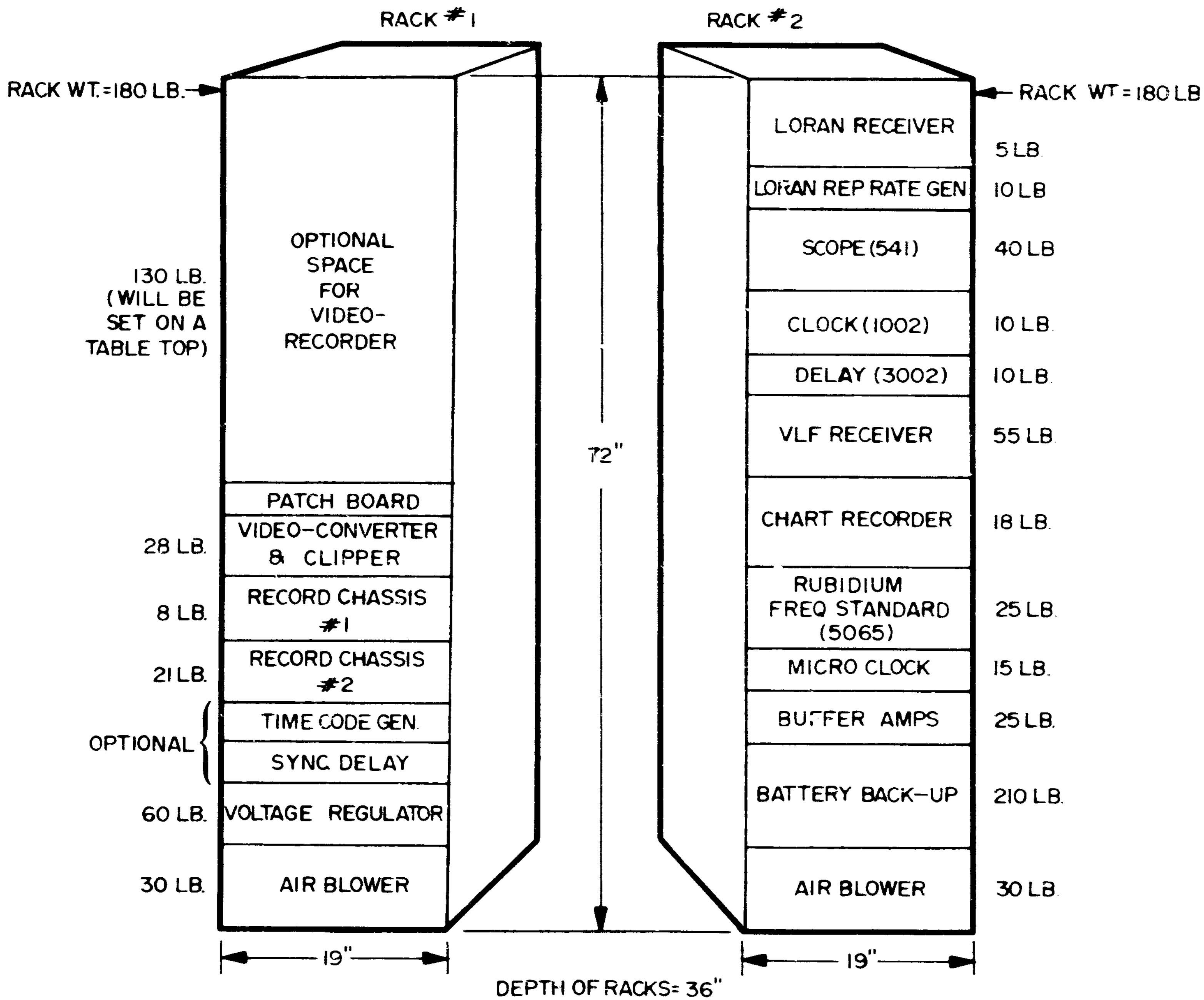

Figure 1. Schematic Diagram of VLBI Racks No. 1 and No. 2.

Table 2
Rack No. 2 (Items and Weight)

Item	Weight (lbs)
Empty Rack	180
Loran Receiver	5
Loran Repetition Rate Generator	10
Display Scope	40
Clock	10
Delay Generator	10
VLF Receiver	55
Chart Recorder	18
Rubidium Frequency Standard	25
Micro Clock	15
Buffer Amplifiers	25
Battery Back-up	210
Air Blower	30
Net weight	633

The following items are not rack mounted and are to be set up as indicated.

Video recorders: It weighs 130 lbs and is 15 inches high, 36 inches wide and 19 inches deep. The video recorder is normally setup on a work desk or a table in front of the racks.

Loran C receiving antenna: It is a loop antenna of 3.5 feet diameter size made of one inch thick metal wire and weighs 10 lbs. It comes with a pedestal and is normally set up outside within 150 feet of the rack-mounted Loran-C receiver.

VLF receiving antenna: It is a loop antenna of 5 feet diameter size and comes with a stand. The total height is 6 feet and it weighs 40 lbs. It is normally set up outside within 150 feet of the rack-mounted VLF receiver.

(c) Optional Test Equipment (Station Furnished): The following equipment are requested for use during the observation program if they are available at the stations:

- Standard 2-channel oscilloscope with delay sweep, model TEK-545 with a dual-trace

- AC voltmeter, HP-400F or a similar model

- 50 ohm variable attenuators up to a range of 100 db

These test equipment shall be set up in front of the VLBI racks.

III. INSTALLATION AND TRAINING

(a) VLBI Equipment Installation: The experimenter shall provide designs of VLBI equipment to the ATS operation control at least two weeks prior to the installation of equipment. It is planned to begin the installation on May 3, 1971 at Rosman and Mojave. Prior to that, all pertinent engineering information will be provided to the ground stations to help them in determining the optimum location for the VLBI hardware.

The physical distance between the rubidium frequency standard and the 125 MHZ synthesizer of the station C-band receiver system can be of the order of 100 feet.

The installation of equipment shall be done in such a way that there will be access to the back of the racks. The racks are mounted on casters and can be easily moved. However, it is not advisable to move them unless it is absolutely necessary since there are many interconnecting cables between the two racks.

The VLBI equipment is connected to the station equipment to derive the 70 MHZ IF from the receiver back-end for the VLBI video converter, to derive 115-120 volts/60 cps electrical power from the station power supply and to drive the station receiver system using the 5 MHZ signal from the VLBI rubidium standard. The connections will be made in such a way that the VLBI can be disconnected momentarily to return the stations to normal operation.

As mentioned earlier, the VLBI system requires 115-120 volts/60 cps electrical power. It is estimated that 3 kilowatts of power is needed with all the systems operating.

The VLBI equipment will be installed at Rosman and Mojave by GSFC and Smithsonian Astrophysical Observatory (GSFC contractor) personnel. Assistance by one or two station personnel (technicians) at each station for two or three days is sufficient for equipment installation.

(b) Check-out and Calibration: After the installation of equipment, the experimenters will check-out and calibrate the VLBI system. At that time, they will demonstrate the operational and maintenace procedures of the VLBI system to the ATS ground station personnel. They will also provide sufficient information

to the ground station personnel to enable them to maintain the equipment and conduct the experiment. An instruction sheet on VLBI equipment maintenance and data acquisition procedures shall also be provided. This will be accomplished during the first week of May for the Rosman-Mojave experiment.

The VLBI system does not generate any RFI (Radio Frequency Interference) and is fairly immune to external RFI. However, it is advisable not to locate extremely strong RFI sources close to the VLBI system.

(c) Bandwidth Power & Modulation Requirements:

Electrical Power: 115-120 volts/60 cps
Total instantaneous power estimate is 3 kilowatts with all the systems running.

Receiver Bandwidth: We expect the satellite C-band transponder to be operating in the frequency translation mode (6212 MHZ uplink, 4119 MHZ downlink).

A receiver bandwidth of 2 MHZ is sufficient.

Modulations: The following carrier frequency modulations are requested during VLBI data acquisition.

a. Constant density analog noise
b. Pseudo random sequence (2047 sequences repeated at a rate of 1 to 3 megabits/sec. The bit rate will be changed.
c. Harmonic side tones (all the range tones turned on simultaneously)

The plan for using these modulations is outlined in the test schedule.

IV. TEST SCHEDULE

(a) Definition of Fundamental Modes:

Table 3
Calibration Mode (C): 16 Minutes

Duration (min)	Function
3	R_C^* (Rosman) + R_{VHF}^{**} (Mojave)
5	Transition***
3	R_C (Mojave) + R_{VHF} (Rosman)
5	Transition

*R_c refers to C-band ranging
**R_{VHF} refers to VHF ranging
***Transition period is used for equipment switchover, calibration and other purposes.

Table 4
VLBI Mode 1 (V-1): 14 Minutes when done once
11 Minutes for each additional mode

Duration (min)	Function	Comments
3	R_C (Mojave)	Range modulation only
1	Buffertime	–
6	VLBI data acquisition	Use of predetermined signal modulation at Rosman C-band transmitter
1	Buffertime	
3	R_C (Rosman)	

(b) Specific Experimental Missions: The fundamental modes of observation (C, V-1 and V-2) are integrated in various ways to come up with time blocks of experiment which are then incorporated in the overall experimental plan based on the extent of availability of ATS-3 satellite time and ground operation support at Mojave and Rosman. The three experimental missions (time blocks of experiment incorporating various alternate features) that are planned are:

1. 3-hour normal mission
2. 3-hour abnormal mission
3. 12-hour mission

Table 5
VLBI Mode 2 (V-2): 41 Minutes

Duration (min)	Function	Comments
5	Transition	Equipment calibration or test period
15	Antenna steering**	
16	Radio star observation*	Not more than 3 radio stars
5	Transition	

*The radio star observation will depend on the ability of the Mojave and Rosman antenna systems to simultaneously steer in real-time. A paper tape input in proper format will be provided containing azimuth and elevation angle information.
The function consists of the antenna pointing towards a predetermined radio star in the sky and following it in real-time using the azimuth and elevation angle information. This is similar to tracking a near-earth orbit satellite. The radio star observation incorporates tracking maneuvers.
**Antenna steering consists of switching from one radio star to another and then following the new source in the observation mode. The 15 minutes of steering time is provided to enable the antenna systems to switch from one tracking mode to track in another at a different point in the sky.

These missions are described in greater detail in the following tables. In practice, it may require more than the time mentioned for each particular mission to successfully complete all the assigned functions or modes (V-1, and V-2) in sequence. It is stressed that the time schedule should be used as a guideline and it is not mandatory to strictly adhere to the time schedule. However, there are a couple of ground rules which shall be followed during each observation period.

(a) Each experiment mission shall begin with a C mode and end with a C mode. The best estimate for a C mode is 16 minutes. If the total allocated time for the experiment is 3 hours, at (t + 180-16) minutes, the stations shall terminate other modes of operation and switch on the final C mode so that the experiment can be completed within the assigned 180 minutes.

The 15 minutes breather provided in the middle during a 3-hour mission is to allow for any unforeseen delays so that the experiment can catch up with the schedule. If everything is working perfectly and the experiment is on schedule, it shall be used as a break.

(b-1) <u>3-Hour Normal Mission:</u> This is an experimental mission which requires 3 hours of ATS-3 satellite time and involves only modes C and V-1. The time sequence of this mission operation is described in the following table.

Table 6
Sequential Description of 3-Hour Normal Mission
t is the station time (EST or UT) in hours and minutes
at the beginning of the experiment

Begin Time (min)	Duration (min)	Operation Mode	Coordination and Comments
t + 0	5	Equipment warm up	Mojave and Rosman VHF/C-band ranging coordination
t + 5	16	C	
t + 21	14	V-1 (First one)	1. C-band ranging co-ordination between Mojave and Rosman 2. VLBI observation coordination 3. Modulation scheme on a predetermined plan
t + 35	11	V-1	
t + 46	11	V-1	
t + 57	11	V-1	
t + 68	11	V-1	
t + 79	11	V-1	
t + 90	15	Breather	–
t + 105	14	V-1 (First one)	1. C-band ranging co-ordination between Mojave and Rosman 2. VLBI observation coordination 3. Modulation scheme on a predetermined plan
t + 119	11	V-1	
t + 130	11	V-1	
t + 141	11	V-1	
t + 152	11	V-1	
t + 163	16	C	
t + 179	0	End	

(b-2) 3-Hour Abnormal Mission: This experimental mission involves a combination of modes C, V-1 and V-2 and is planned for a few days only during a four week experimental period. As mentioned earlier, the V-2 mode requires that the antennas at Rosman and Mojave are steered simultaneously to track specific radio stars. If V-2 mode cannot be accomplished, the 3-hour abnormal mission will be changed to 3-hour normal mission described earlier. The time sequence operations in this mission are described in the following table.

Table 7
3-Hour Abnormal Mission
Sequential Description of Experimental Mission

Begin Time (min)	Duration (min)	Operation Mode	Comments and Coordination
t + 0	5	Equipment warm up	VHF and C-band ranging coordination between Mojave and Rosman
t + 5	16	C	
t + 21	14	V-1 (First one)	1. C-band ranging coordination 2. Use of preplanned signal modulation scheme during VLBI mode
t + 35	11	V-1	
t + 46	41	V-2	Steering of antennas towards selected stellar sources and maintaining track
t + 87	15	Breather	
t + 102	41	V-2	
t + 143	14	V-1 (First one)	1. C-band ranging coordination 2. Use of preplanned signal modulation scheme during VLBI mode
t + 157	11	V-1	
t + 168	16	C	
t + 184	0	End	VHF and C-band ranging coordination between Mojave and Rosman

(b-3) 12-Hour Mission: This experimental mission will be conducted only once or twice during a 4 week observation program. It consists of 4 separate observation schemes. They are 3 hours apart and each will last for 106 minutes. The total observation time will therefore not exceed 7 hours and 4 minutes. Each observation scheme (106 minutes duration) is composed of Modes C, V-1 and V-2. In the event that V-2 mode cannot be accomplished, it is replaced by V-1 mode.

Table 8
12-Hour Mission Table Schedule

Observation Scheme Number	Begin Time (Hours)	End Time (Hours)
1	t + 0	t + 1 h 46 min
2	t + 3	t + 4 h 46 min
3	t + 6	t + 7 h 46 min
4	t + 9	t + 10 h 46 min

Each observation scheme is conducted as described in the following table.

Table 9
106 Minute Observation Scheme Time Schedule

Begin Time (min)	Duration (min)	Operation Mode	Comments and Coordination
t + 0	5	Equipment warm up	—
t + 5	16	C	VHF and C-band ranging coordination between Mojave and Rosman
t + 21	14	V-1	(a) C-band ranging coordination (b) Use of predetermined signal modulation during VLBI observation
t + 35	41	V-2	Simultaneous antenna steering requirement
t + 76	14	V-1	(a) C-Band ranging coordination (b) Use of predetermined signal modulation during VLBI observations
t + 90	16	C	VHF and C-band ranging coordination between Mojave and Rosman
t + 106	0	End	

(c) 4-Weeks Experiment Plan: The experiment is planned to be conducted 4 days a week, 3 hours a day except on one or two occasions when it shall be conducted during a 12 hour period. The schedule is as follows:

Table 10
(C-1) First Week Test Plan

Day	Experiment Mission	First Alternative	Second Alternative
1	3-Hour Normal	–	–
2	3-Hour Normal	–	–
3	3-Hour Normal	–	–
4*	3-Hour Normal	–	–

Table 11
(C-2) Second Week Test Plan

Day	Experiment Mission	First Alternative	Second Alternative
1	3-Hour Normal	–	–
2	3-Hour Abnormal	3-Hour Normal	–
3	12-Hour Mission	3-Hour Abnormal	3-Hour Normal
4*	3-Hour Normal	–	–

Table 12
(C-3) Third Week Test Plan

Day	Experiment Mission	First Alternative	Second Alternative
1	3-Hour Normal	–	–
2	3-Hour Abnormal	3-Hour Normal	–
3	12-Hour Mission	3-Hour Abnormal	3-Hour Normal
4*	3-Hour Normal	–	–

*Fourth day of operation is subject to the availability of satellite time and ground operation support at Mojave and Rosman. If only 2 hours are allowed the modified 2-hour normal mission described in Table 14 is followed.

Table 13
(C-4) Optional Fourth Week Test Plan*

Day	Experiment Mission	First Alternative	Second Alternative
1	3-Hour Normal	–	–
2	3-Hour Abnormal	3-Hour Normal	–
3	3-Hour Normal	–	–
4**	3-Hour Normal	–	–

Table 14
Modified 2-Hour Normal Mission

Begin Time (min)	Duration (min)	Mode of Operation
t + 0	5	Equipment warm-up
t + 5	16	C
t + 21	14	V-1 (First one)
t + 35	11	V-1
t + 46	11	V-1
t + 57	11	Breather
t + 68	14	V-1 (First one)
t + 82	11	V-1
t + 93	11	V-1
t + 104	16	C
t + 120	0	End

*The fourth week of operation is optional.
**Fourth day of operation is subject to the availability of satellite time and ground operation support at Mojave and Rosman. If only 2 hours are allowed the modified 2-hour normal mission described in the above table is followed.

V. SUPPORT

The experiment shall be conducted under the technical direction of Dr. J. Ramasastry, Code 551, GSFC. During the experiment, one SAO engineer will be present at each of the two stations (Mojave and Rosman). He shall be responsible for data acquisition and coordination. He will also be responsible for disconnecting the VLBI system whenever required. However, the ATS ground support personnel (not more than two at each station) will be trained to be able to independently operate the VLBI system. Manpower support to conduct ranging during the experiment is required. ATS-3 VHF Faraday rotation data and pressure,

temperature and humidity data are also requested from both Mojave and Rosman.

Video tapes will be shipped from GSFC to Mojave and Rosman for recording VLBI data. Once every two days, the tapes (with the data) have to be shipped to Goddard by air-mail.

Data analysis in the form of computer correlation of reformatted video tape data from Mojave and Rosman will be accomplished primarily at the Smithsonian Astrophysical Observatory. Detailed data processing will be conducted using GSFC computers. More details on the data analysis and applications can be found in the GSFC document X-551-70-432, November 1970, titled "Very Long Baseline Interferometry Using ATS-3 and ATS-5 Satellites" by J. Ramasastry et al.

VI. OPERATIONAL NOTES

The following additional operations may be requested of the ATS ground station personnel:

(a) To test, prior to the experiment, the radio antenna steering capabilities at Rosman and Mojave for radio star observation. The input data for the pointing at the target sources will be provided in format by GSFC personnel.

(b) To stagger by one hour per day the time of initiation of the 3-hour missions.

(c) To transmit signals during some VLBI modes 1 and 2 at certain power levels as specified by prior arrangement with GSFC personnel.